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# The Quality of Price Discovery and the Transition to Electronic Trade: The Case of Cotton Futures

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**Abstract:** This paper studies the effect of electronic trade on the quality of market price discovery, using the Intercontinental Exchange (ICE) cotton futures market as a laboratory to measure market quality under periods of floor trade, parallel floor and electronic trade, and electronic-only trade. Using random-walk decomposition methods pioneered by Hasbrouck (2007), we decompose intraday variation in cotton prices into two components: one related to information about market fundamentals and one a “pricing error” related to market frictions such as the cost of liquidity provision and the transient response of prices to trades. We describe the properties of this pricing error to characterize market quality under both floor and electronic trading systems. Unlike previous studies, we analyze more than the average magnitude of the pricing error. Each day, we calculate statistics that describe market quality on that day, and we study their trend, variance and persistence.

**Key words:** cotton, futures markets, market quality, volume, electronic trading.

**JEL Classification Numbers:** Q0, F0.

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Commodity futures markets have recently changed the process by which futures contracts are traded.. Whereas for decades, trades were face-to-face transactions between buyers and sellers who met on a trading floor, exchanges have introduced electronic platforms where computer algorithms match offers to buy and sell. In the past decade, electronic trading platforms have been introduced, operating along side floor trading. In some markets, floor trading has been eliminated all together. What impact might this change have? The theoretical literature on electronic trading suggests that transactions costs may differ across trading platforms.

The market microstructure literature in economics and finance recognizes that economic transactions are not costless or frictionless. Traders, whether buyers or sellers, incur an implicit cost that is the difference between the actual transaction price and the price justified by the relative scarcity of the underlying asset. In commodity markets, this price is generally thought of as the price justified by supply and demand balance based upon all available knowledge at a moment in time.

This paper studies the effect of electronic trade on the quality of market price discovery, using the Intercontinental Exchange (ICE) cotton futures market as a laboratory to measure market quality under periods of floor trade, parallel floor and electronic trade, and electronic-only trade. Using random-walk decomposition methods pioneered by Hasbrouck (2007), we decompose intraday variation in cotton prices into two components: one related to information about market fundamentals and one a “pricing error” related to market frictions such as the cost of liquidity provision and the transient response of prices to trades. We describe the properties of this pricing error to characterize market quality under both floor and electronic trading systems. Unlike previous studies, we analyze more than the average magnitude of the pricing error. Each day, we calculate statistics that describe market quality on that day, and we study their trend, variance and persistence.

Our analysis considers price discovery using high frequency, transaction-by-transaction data. In our case, we consider the ICE cotton futures market for the period from 2006 to 2009. Our data on the cotton market contains periods where floor trading has been eliminated. We compare

the average, variance, and trend in market quality before and after the introduction of electronic trading and the subsequent elimination of floor trading. This approach enables us to test three hypotheses in addition to tests of average market quality. First, is the market under electronic trade more vulnerable? That is regardless of average pricing errors, are large-pricing-error days more likely? Second, even if market quality was poor immediately after the elimination of floor trading, did it improve as traders adapted to the new system? Third, how does market quality vary with fundamental volatility?

### **Background on the cotton market**

Cotton futures present an attractive case for analyzing the transition to electronic trade because of their recent price behavior . In late February and early March 2008, ICE cotton futures prices were extremely volatile. The nearby futures price rose from 70 cents per pound in mid-February to a high of almost 93 cents on March 3rd, before falling back below 70 cents by mid-March. Nearby futures moved up or down the limit set by the exchange on 12 of 18 consecutive trading days. Volatility of this magnitude was unexpected and significant: high prices were not accompanied by low inventories or other bullish fundamentals and numerous merchant firms who used cotton futures to hedge price risk were forced to exit the industry due to margin call-related losses caused by these price moves.

One potential explanation for volatility in cotton futures markets is the transition from open-outcry to electronic trade. Curiously, March 3rd, the day at the center of the 2008 price spike in cotton, was the first day without trading on the floor. In the words of market analyst Mike Stevens: “Everything changed in March 2008. That was when electronic trade came in. The price-discovery mechanism began to get somewhat shaky” (Hall, 2011). Reaction to the 2008 price spike suggests that the cotton futures market may behave differently under electronic trade than it had over many years of floor trading. The signal provided by futures prices may be polluted by additional noise due to the electronic trading mechanism. Put differently, observed prices may deviate from economically efficient prices for some period of time.

In response to the events of March 2008 in the cotton futures market, the Commodity Futures Trading Commission commissioned a report that considered “...the trading patterns of market participants, the broad increase in commodity prices in general, the impact of the presence of certain market participants in the market, the possible tightening of credit conditions, the impact of price limits in general, and the potential that prices may have been manipulated” (Commodity Futures Trading Commission, 2010). They concluded that trading and price patterns in cotton were not consistent with any sort of market manipulation and that the elimination of floor trading was only coincidental to observed price volatility, not the cause.

Even if electronic trading was not responsible for the events of March 2008, the ICE cotton futures market is an attractive laboratory in which to examine the impact of electronic trade on price discovery. In the relatively short period between February 2007 and March 2008, ICE introduced electronic trading and closed the trading pits. This creates three periods of floor trade, parallel floor and electronic trade, and electronic-only trade that should be closely related in terms of the fundamentals underlying the determination of the value of cotton. The composition of traders through this period should also be relatively stable.

### **Differences between electronic and open-outcry futures trading**

Electronic and open outcry futures markets have the same goals: to facilitate price discovery and risk management through hedging. Each system provides a venue for traders to buy and sell futures contracts. Electronic trade features an open limit order book. Whereas under open-outcry, traders shout out their bids and offers (the prices at which they are willing to buy or sell), in electronic markets, bids and asks are posted in the limit order book and viewable by all traders. They reside in the order book until filled or withdrawn. A computer algorithm matches incoming orders to the standing limit orders in the book.

We evaluate the merit of each system based upon the cost of trading under that system. Ates and Wang (2005) provide a useful and comprehensive summary of the differences between electronic and open-outcry trading systems. They divide these differences into two categories: operational

and informational.

Operational differences relate to order processing and fixed per-transaction costs of trading. Electronic trading uses high-speed communications systems to rapidly deliver orders and match buyers and sellers. Orders are usually matched according to a “first in, first out” rule. “Out-trades,” canceled trades on the floor where buyer and seller report incongruent information about the agreed price and size of the trade, are eliminated. Further, electronic trade does not require a physical presence in a capacity constrained trading pit, implying that the cost of participation is lower. In general, electronic trading should improve order processing and reduce transactions costs.

Informational differences relate to the role that prices and trades play in conveying information to market participants. Electronic and open-outcry trading systems provide different types and amounts of information to traders, particularly information about the actions and intentions of other traders. Fundamentally, open outcry markets allow traders to observe who is providing liquidity by bidding or offering. It may also be possible to observe when orders are coming from off the floor and when floor brokers are trading to balance their positions. Traders in the open-outcry system can choose their counterparties. In addition, the massing of all traders in one physical location provides additional sensory cues to traders<sup>1</sup>. In general, the open-outcry system provides traders with additional information not available on the electronic trading screen.

This information may mitigate the adverse selection problem faced by any trader who makes markets or provides liquidity. As noted by Copeland and Galai (1983) and Glosten and Milgrom (1985), when a trader shouts a bid or offer or when they submit a limit order into the book they expose themselves to counterparties with potentially better information about the fundamental value of the commodity. This creates an adverse selection problem. Informed counterparties will only hit this bid or offer if they expect to make positive profits, implying an expected loss for the market maker. In limit order book markets, quotes posted by market makers are valid until withdrawn. In open outcry, quotes are valid only so long as “breath is warm”. This means that quote monitoring and quote revision are more costly in the electronic trading environment and may lead market

makers to widen bid-ask spreads.

Under both trading systems, the potential for adverse selection and the process of quote-setting that determine the cost of transacting may vary over time. Franke and Hess (2000) hypothesize that the attractiveness of electronic and open-outcry platforms will vary with the intensity of the arrival of new information about market fundamentals. To the market maker, the information value of knowing who you are trading with increases as information intensity increases. This implies that neither system may be strictly more competitive than the other, but the effectiveness of system varies depending on the trading situation. For this reason, average measures of the quality of price discovery over long time periods may not fully measure the cost of transacting. Higher moments of the distribution of transactions costs are also important.

### **Methods for comparing electronic versus open-outcry**

The theoretical literature reviewed above suggests that switching to electronic trading may positively or negatively impact the cost of trading. A growing empirical literature assesses the impact of the transition to electronic trade. This work is complicated by the nature of the problem: many of the theoretical constructs such as the degree to which traders are informed and the fundamental value of the underlying commodity are inherently unobservable. Economists have developed measures to compare transactions costs in open-outcry and electronic markets. We review literature on bid-ask spreads below. Other methods for assessing price discovery include estimation of the proportion of price discovery that occurs in each market, in this case in the floor and electronic markets. Two methods commonly used to estimate price discovery shares are the information shares technique of Hasbrouck (1995) and the common long-memory factor weights method of Gonzalo and Granger (1995).

#### *Bid-ask spreads and market liquidity*

The most general approach to measuring the effect of electronic trade uses the bid-ask spread as a measure of transactions costs. As noted above, electronic trade should improve order processing,



which reduces the compensation required by market makers to stand on the other side of incoming order flow. However, asymmetric information may cause market makers to widen spreads to compensate for expected losses to better informed traders. A reduced-form econometric approach regresses the bid-ask spread on variables thought to determine the cost of transacting. In practice, these are usually things found in exchange-provided data, such as trading volume and price volatility.

Empirical analysis of liquidity using bid-ask spreads has been hampered by the lack of reporting of spreads in open outcry futures markets. Often only transactions prices or end-of-day prices are available. Various estimators have been developed to approximate bid-ask spread levels using such data. These measures generally estimate an average liquidity or spread level over some period of observation. The most common, due to Roll (1984) uses the serial covariance of successive price changes. The formula is:

$$(1) \quad RM = 2\sqrt{-cov(\Delta p_t, \Delta p_{t-1})}$$

Other measures include the Thompson and Waller (1988) absolute average price change measure:

$$(2) \quad TWM = \frac{1}{T} \sum_{t=1}^T |\Delta p_t|$$

Smith and Whaley (1994) derives a similar absolute average price change based measure. The authors of these measures provide some theoretical justification and empirical conditions under which their spread estimators are valid. These spread estimators are an imperfect means of measuring bid-ask spreads market liquidity. To that end, some of the papers studying the move to electronic trading test these measures against available bid-ask spread data. For example, Bryant and Haigh (2004) suggest that absolute average price change measures perform better than serial covariance estimators at estimating spreads in the their data on coffee and cocoa futures.

Three recent studies of electronic trade for agricultural futures use a bid-ask spread estimation approach, though they reach different conclusions. Bryant and Haigh (2004) consider the switch

to electronic trade in London International Financial Futures and Options Exchange cocoa and coffee futures in 2000. They regress daily average bid-ask spread against trading volume, price volatility, and an indicator for the presence of electronic trade. They find that average spreads are significantly wider under electronic trade than under open-outcry. In contrast, Frank and Garcia (2011) consider live cattle and live hog markets at the Chicago Mercantile Exchange under the side-by-side operation of electronic and open-outcry trading systems. They find that increases in the proportion of trading volume occurring on the electronic platform are associated with reductions in estimated bid-ask spreads. Martinez et al. (2011) document a similar effect for Chicago Board of Trade corn, wheat, and soybeans futures where electronic and floor trading operate in parallel.

Bryant and Haigh (2004) suggest that the negative effect of electronic trade found their study is the result of the information asymmetry and adverse selection problem presented earlier. However, these reduced form studies look only at transaction cost outcomes and fail to consider the presence of those things that would cause the adverse selection problem. Such things include the presence of informed traders and the degree to which prices follow fundamentals. Because these things are inherently unobservable, considerable work in the finance literature has gone into development of structural models that can identify these phenomena.

### **Random-walk decompositions in a microstructure framework**

Many market microstructure models suggest that prices can be decomposed into parts due to the fundamental asset value and due to frictions in the trading process that may be influenced by market organization (Hasbrouck, 2007, p. 23). Commodity price changes due to fundamentals involve the incorporation of information about underlying supply-and-demand relationships. These changes are unpredictable and long-lived and are often represented using a random-walk in a microstructure framework. Defining the fundamental value of the asset at period  $t$  as  $m_t$ , the evolution of the fundamental value over time is:

$$(3) \quad m_t = m_{t-1} + w_t,$$

where  $E(w_t) = 0$ ,  $E(w_t^2) = \sigma_w^2$ ,  $E(w_t, w_{t-k}) = 0$  for  $k \neq 0$ . Innovations to this time series,  $w_t$ , may be interpreted as the arrival of new information about fundamentals.

Observed transaction prices,  $p_t$  may not always fully reflect underlying fundamentals so that  $p_t \neq m_t$ . Deviations of the observed price from the fundamental value are represented as a “pricing error” term, denoted as  $s_t$ , so that observed prices are represented as:

$$(4) \quad p_t = m_t + s_t.$$

The pricing error can generally be thought to impound various “microstructure effects” related to the arrival of orders into the market at period  $t$ . We want to evaluate the magnitude of these microstructure effects.

#### *Interpretation and estimation of the random-walk decomposition model*

Microstructure models relax the assumption that each trade is costless and unconstrained. These constraints prevent observed prices from being equal to the fundamental value. One simple conception of the pricing error,  $s_t$ , is the half spread a buyer or seller would implicitly “pay” to have their transaction occur immediately. A buyer might be thought to pay  $s_t$  (and a seller thought to pay  $-s_t$ ) for a transaction to occur. Of course, other factors might cause prices to deviate from fundamentals for significant periods of time, so that bid-ask spreads may be narrow though prices are far from fundamentals (i.e.  $s_t$  is large). The identification of  $s_t$  and its standard deviation,  $\sigma_s$ , can provide an alternative measure of the cost of transacting. If  $\sigma_s$  is large, then prices may be unmoored from fundamentals for significant periods of time.

Hasbrouck (1993) presents a version of the random-walk decomposition model that relates things that we can observe to theoretical constructs such as the pricing error. We can observe changes in prices,  $r_t = p_t - p_{t-1}$ , and trade indicators,  $x_t$ , which classify trades based on whether they were initiated by buyers or sellers. His model provides a closed-form solution for the pricing error and the pricing error variance that depend on parameters that are derived from a simple,

estimable model of joint price change and trade indicator dynamics.

Assuming observed price and trade dynamics follow a simple vector autoregression (VAR) process truncated at some reasonable lag length, then the VAR model:

$$(5) \quad \Delta p_t = \sum a_i \Delta p_{t-i} + \sum b_i x_{t-i} + e_{1t}$$

$$(6) \quad x_t = \sum c_i \Delta p_{t-i} + \sum d_i x_{t-i} + e_{2t},$$

can be related to a vector moving average (VMA) representation. Hasbrouck (1993) assumes that the pricing error is entirely correlated with information about the fundamental underlying price and with the direction of trade so that pricing errors arise from “adverse selection effects... and from lagged adjustment to information”. Under this assumption, the pricing error,  $s_t$ , can be expressed as a function of the coefficients from the VMA process and the residuals from the VAR.

The Hasbrouck (1993) methodology has been used to assess the transition to electronic trade. Tse and Zobotina (2001) study the transition of FTSE 100 stock index futures from open-outcry to electronic trade in 1999. They calculate average market quality over two three-month trading periods before and after the switch and find that the floor-trade period is associated with higher market quality in the sense that the pricing error variance is lower over this entire period. We expand on this methodology in the section by considering a daily pricing error variance measure applied to the case of ICE cotton futures.

## Data

The model requires data on two variables, returns and trades. We generate these variables using intraday tick-by-tick transaction data for ICE cotton futures acquired from TickData Inc. This dataset records the time and price of each futures market transaction. Transactions are time-stamped to the second. Electronic trades include the number of contracts exchanged; open-outcry trades do not report trade quantity. For our current analysis, we consider transactions for one nearby contract each trading day. We generally use the most-active nearby contract, rolling to the next contract

on the twentieth day of the month prior to the delivery month. In practice, the most-active nearby contract is usually the nearest to delivery, except for the October contract which is more lightly traded than the December contract. Therefore, we essentially roll from the July to the December contract during the June roll period. We supplement the transaction-level data with daily price and volume information from Commodity Research Bureau.

Following Hasbrouck (1993), we ignore natural time and treat the data as an untimed sequence of observations. Returns are calculated as the difference between the current and previous transaction. Trade classifications cannot be made relative to quoted bids and offers because quote data is unavailable for the open-outcry period, so we cannot use the widely-used trade classification algorithm of Lee and Ready (1991). Instead, we employ a simple tick rule whereby the trade is classified as buyer-initiated if the previous price was lower than the transaction price and seller-initiated if the previous price was higher than the transaction price. When the previous price is the same as the transaction price, the trade is classified the same as the previous trade classification. Since we do not have transaction volume for trades on the floor, we create our trade variable as an indicator variable that takes on the value -1 when a trade is seller-initiated and 1 when a trade is buyer-initiated. Though the tick rule considers less information than quote-based trade classification rules, validation studies such as Ellis, Michaely, and O'Hara (2000) suggest that the difference in trades misclassified may not be large.

We divide the data into three periods: floor trade, parallel floor and electronic trade, and electronic-only trade. The parallel trade period contains 269 trading days between February 2, 2007 and February 29, 2008. We select a similar number of floor-only and electronic-only trading days to complete our dataset. The floor-only period is January 3, 2006 to February 1, 2007. The electronic-only period is March 3, 2008 to March 27, 2009. During the period covered by our dataset, the floor-trading session runs from 10:30am to 2:15pm Eastern Time. The electronic trading session runs from 1:30am to 3:15pm.

## Results

We estimate the two-equation VAR model for returns and trades for each day, truncating any dependencies at five lags. We calculate the variance of the pricing error using the formula provided by Hasbrouck (1993), again truncating the vector moving average representation of the model at five lags. We also calculate a measure of observed price volatility by calculating the standard deviation of observed intraday transaction prices.

Table 1 presents summary statistics for daily data on prices, trading volume, and market quality for the entire sample and for the three subperiods of floor-only, parallel floor and electronic, and electronic-only trade. Average price levels across the three periods were relatively similar, however price variability in the parallel trade and electronic-only trade periods was considerably higher. Similarly, intraday price volatility, as measured by the standard deviation of intraday prices was higher and more variable in the electronic trading period.

Under electronic trade more transactions occurred, but the volume per transaction was lower. Daily trading volume in the floor-only and electronic-only periods was similar: approximately 11000 contracts were traded daily in these periods. However, the number of trades grew dramatically, from an average of 653 under floor-only trade to 3712 under electronic-only trade. It appears that large market orders handled in a single trade in the pit are now split into a series of smaller trades in order to be processed on the screen.

The summary statistics for the market quality measure in table 1 suggest that average market quality was poorer and more variable in the electronic-only period. The standard deviation of daily market quality measure was an order of magnitude higher during this period relative to previous periods. This conclusion is misleading because these statistics are greatly affected by the presence of outlier trading days around the period of the price boom and bust in March 2008. The maximum pricing error variance of 0.092986 was calculated for the March 4, 2008 trading day. On this day, the nearby May 2008 cotton futures contract traded up the limit most of the day. The market quality measure may deviate dramatically when markets cannot incorporate new information about prices because of exchange-imposed limits to trading. On limit-move days, the cost of transacting may be

very high because many traders are facing margin calls and market makers face more uncertainty in quote-setting<sup>2</sup>.

Excluding the period immediately surrounding the 2008 price spike, average market quality was better under the electronic-only trade. Figure 1 plots the pricing error variance across our entire sample period on a logarithmic scale. Except for a number of periodic blips, the pricing error variance decreases upon the introduction of electronic trade in 2007 and settles to a lower level after floor-trading is eliminated in 2008. If we eliminate March 2008 observations from the electronic-only period, the average pricing error variance is 0.000046 with a standard deviation of 0.000101, lower than the standard deviation of the pricing error in the preceding periods. However, the coefficient of variation in the electronic-only period is higher (2.196) than during the floor-trading period (0.604). Therefore, we conclude that market quality has become more variable in the transition to electronic trade.

## **Discussion and conclusions**

We find that the introduction of electronic trade has improved the quality of price discovery in the ICE cotton futures market. The variance of the pricing error, a measure of the cost of transacting, is lower during the electronic-only trading period than during the periods of floor-only and parallel floor and electronic trade that directly preceded it. The elimination of floor trading for cotton futures coincided with a period of extremely volatility prices and high trading volume. Measured market quality during this period was poor, but our results cannot establish a causal relationship between lower market quality and electronic trade. Market quality improved significantly in the months that followed the introduction of electronic trading. It appears that traders adapted to the new system and did so quickly. However, our results also show that market quality became more variable upon the elimination of floor trading.

Our analysis of market quality in the cotton futures market does not yet establish why market quality improved or why it became more volatile when the market moved to the screen. We do observe more transactions during the electronic-only period, suggesting that large trades that were

matched in the pit are being divided into smaller trades on the screen. Whether dealing in smaller volume per trade helps traders offer tighter bid-ask spreads or reduces costs related to adverse selection is an open empirical question. Further analysis of market quality in the cotton market should explore this mechanism and others that may explain the reductions in transactions costs.



## Notes

<sup>1</sup>Coval and Shumway (2001) find that changing sound levels in the trading pit forecast changes in the cost of transacting.

<sup>2</sup>Carter and Janzen (2009) review the events surrounding the 2008 spike and discuss the extraordinary margin call risk faced by cotton futures traders at that time.

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## Figures

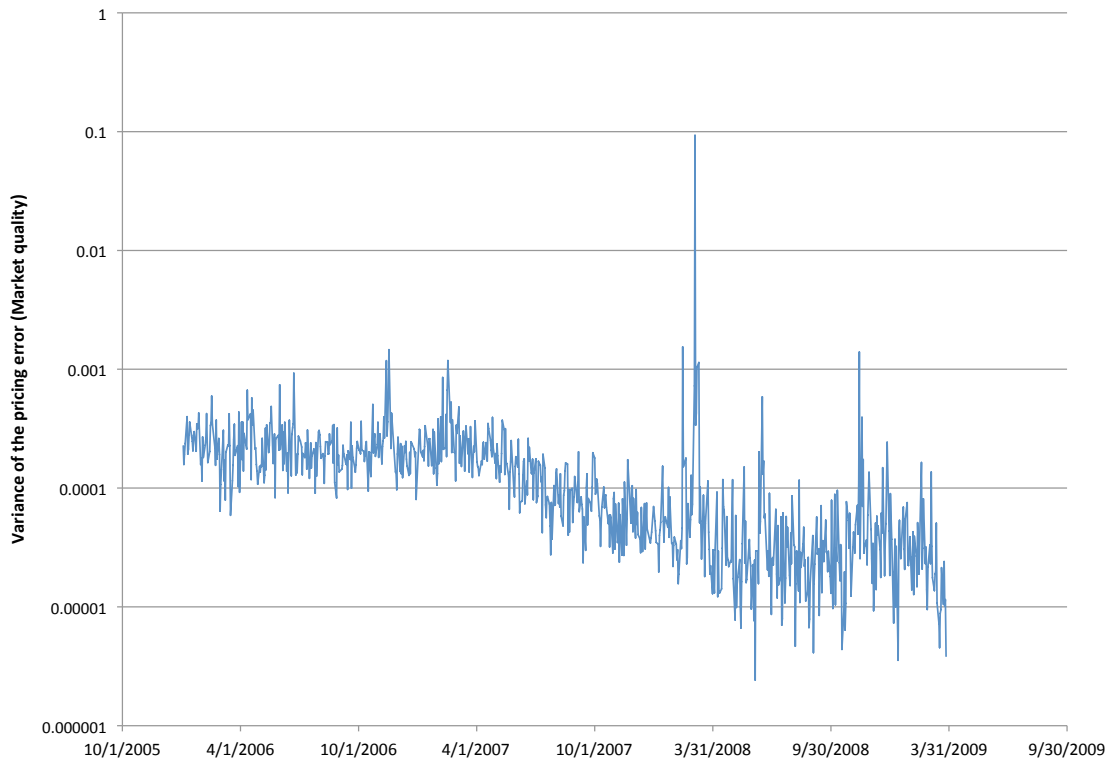


Figure 1: Market quality as measured by variance of the pricing error, January 2006 to March 2009

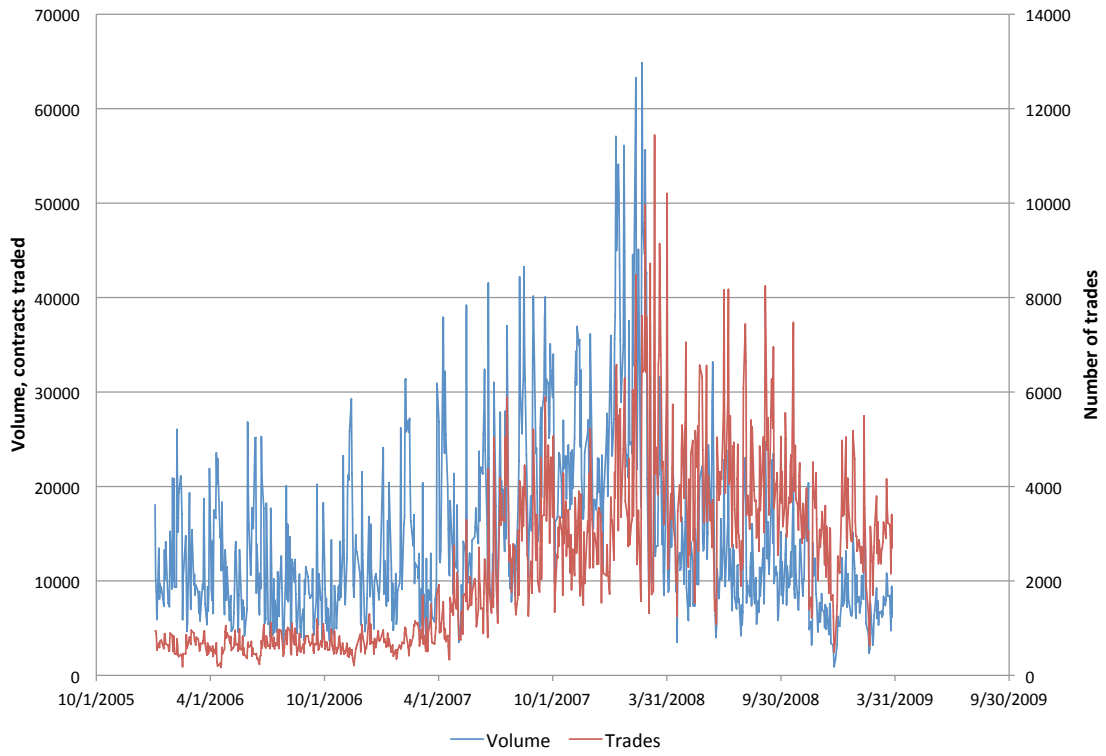


Figure 2: Daily number of trades and trading volume, January 2006 to March 2009

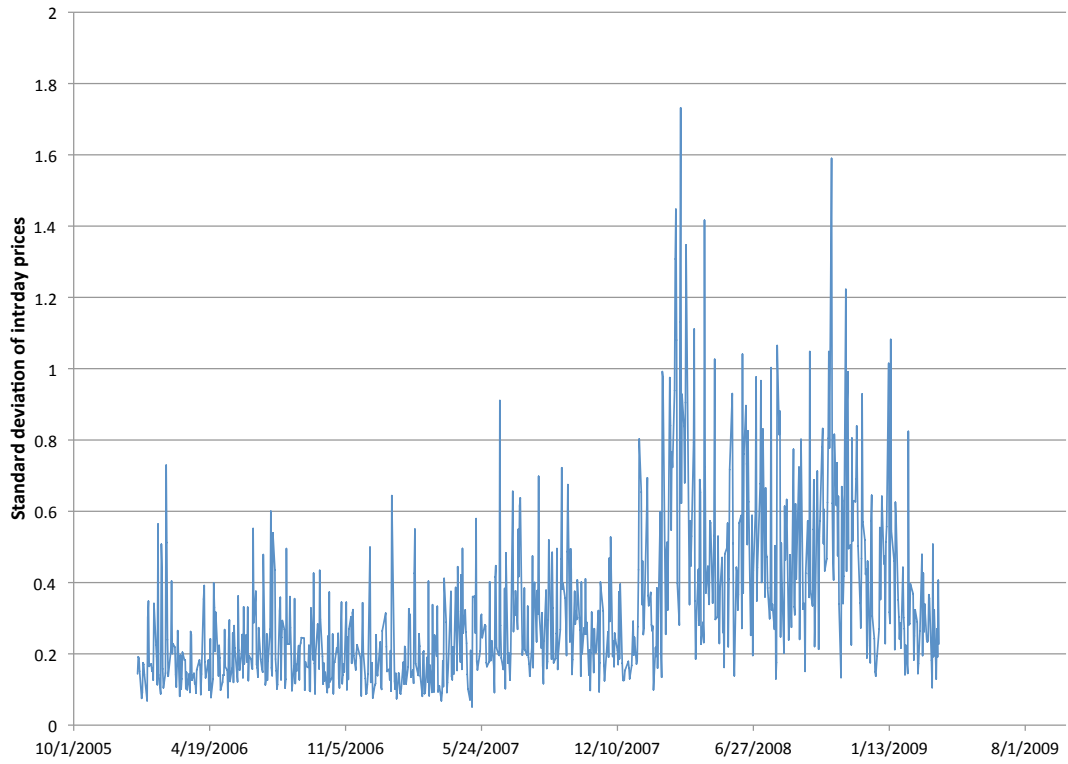


Figure 3: Intraday price volatility, January 2006 to March 2009

## Tables

Table 1: Summary Statistics for Daily Results, January 2006 to March 2009

		Total sample	Trading system subperiods		
			Floor	Parallel	Electronic
Trading days		811	271	269	271
Closing price	Mean	57.87	53.28	60.49	59.87
	St. Dev.	9.51	2.35	7.30	13.45
	Minimum	39.14	47.40	46.92	39.14
	Maximum	89.28	57.34	81.86	89.28
Intraday volatility	Mean	0.328	0.202	0.286	0.497
	St. Dev.	0.236	0.109	0.171	0.281
	Minimum	0.051	0.068	0.051	0.105
	Maximum	1.732	0.729	0.992	1.732
Trading Volume	Mean	14703.27	10874.24	22042.93	11246.79
	St. Dev.	9639.76	5449.41	11549.57	6024.60
	Minimum	915	3263	3505	915
	Maximum	64880	29275	64880	40495
Number of Trades	Mean	2328.43	653.38	2621.93	3712.13
	St. Dev.	1819.86	198.83	1611.63	1579.32
	Minimum	168	168	337	493
	Maximum	11438	1301	9968	11438
Market Quality	Mean	0.000260	0.000240	0.000137	0.000402
	St. Dev.	0.003264	0.000145	0.000152	0.005647
	Minimum	0.000002	0.000059	0.000016	0.000002
	Maximum	0.092986	0.001462	0.001542	0.092986